June 2017

Application to the *Economic Policy Research Network* for support for

research project on developing

THE GREEN REFORM MODEL:

A Model of the Interaction of the Environment and the Danish Economy

Aim and context of the project

The computable general equilibrium REFORM model of the Danish economy developed by the Danish Institute for Economic Modelling and Forecasting (DREAM) is currently used by the Danish Ministry of Finance and the Danish Economic Councils to evaluate the long-run effects of policies aimed at improving the performance of the Danish economy. Drawing on the expertise of the DREAM group, the Ministry of Finance plans to build a new macroeconomic model for Denmark. The long run equilibrium of this model is based on the same data and theory as the REFORM model. We propose to construct the GREEN REFORM model as a direct extension of the REFORM model. The GREEN REFORM model will be able to simulate the environmental effects of Danish economic activity and the economic effects of policy interventions to meet the targets for Danish environmental, energy and climate policy.

The scientific value-added of the project

The GREEN REFORM model will allow

1) a consistent evaluation of the effects of economic policies on key indicators of environmental quality and
2) an analysis of the effects of alternative environmental and climate policies on the level and composition of economic activity.

The goal is to develop a modelling tool which will allow the evaluation of economic and environmental policy within a unified conceptual framework that accounts for environmental as well

as economic effects, thereby facilitating an integrated assessment of the two types of policy. Specifically, the GREEN REFORM model will extend the existing REFORM model in the following ways:

Accounting for natural resource use and emissions of pollutants. The extended model will account for the impact of economic activity in all the different sectors of the Danish economy (73 sectors in the current model) on the emissions of 14 different pollutants considered to be important for environmental quality in Denmark and for Denmark's contribution to cross-border and global pollution. This will require a modeling of endogenous pollution abatement activity and the impact of government regulation on such activity. The model will also allow a detailed mapping of the use of inputs of energy, water and materials in different sectors as well as their generation of various waste products.

A more detailed modeling of key sectors. The GREEN REFORM model will include a more detailed and disaggregated modeling of the following sectors which play a particularly important role in Danish environmental and climate policy: Energy, transport, waste treatment, agriculture, fishery, forestry, and land use more generally. The modeling of the energy and transport sectors will allow for endogenous choices among different technologies with different environmental impacts, and the modeling of agriculture will introduce land as a separate factor of production as well as a more detailed endogenous product mix to describe how the volume and composition of agricultural output and changes in land use affect greenhouse gas emissions and emissions affecting water quality. The more elaborate modeling of the waste treatment sector will allow an evaluation of the environmental and economic effects of policy measures to increase the degree of recycling of waste and raw materials.

Building on the expertise of the senior researchers behind this project (see below), the scientific goal of the project is to set a new and higher standard for the modeling of the interaction of the economy and the environment. One source of inspiration for the modeling work will be the "green" model of the Dutch economy developed by Gerlagh et al. (2002), but the GREEN REFORM model will be more detailed and will capture more aspects of the economy-environment nexus. It will also build on recent advances in the techniques for modeling pollution abatement technologies that allow a calibration of

the model to micro data on the costs of different abatement technologies, exemplified by the contributions by Boeters and Koornneef (2011) and Kuila and Rutherford (2013).

Organization and partners

The work to develop the GREEN REFORM model will be directed by professor Peter Birch Sørensen from the Department of Economics at the University of Copenhagen in collaboration with Peter Stephensen, Research Director of the Danish Institute for Economic Modelling and Forecasting (DREAM). Advice on data availability and data work will be offered by Chief Adviser Ole Gravgård Pedersen who is directing the work in Statistics Denmark to develop Green National Accounts for the Danish economy.

The modeling work will be carried out under the guidance of an advisory group including representatives from the Ministry of Finance, the Ministry of Environment and Food, Statistics Denmark, the Danish Economic Councils, the Danish Council on Climate Change and a leading international expert on environmental economics and green national accounts. The institutions mentioned have already declared their willingness to offer advice.

The project will involve a post doctoral researcher and two Ph.D. students appointed by the Department of Economics of the University of Copenhagen and a member of the staff of the DREAM modeling group. The project will be linked to an existing joint venture between the University of Copenhagen and Statistics Denmark which involves the development of a measure of the stock of "Natural Capital" and a "Green Net National Product" for the Danish economy. This collaborative effort has already received support from the KR Foundation, and one of the two Ph.D. students associated with the present project will be financed by the KR grant. In addition, the Carlsberg Foundation has donated a grant for the project that will allow the appointment of one further Ph.D. student and one post doctoral researcher who will be associated with the project. However, further financial resources will be needed to develop the GREEN REFORM model outlined above. Conditional

on sufficient funding, the time horizon for the modeling work is 3½ years, starting from the fall of 2017.

Expected outcomes

The project will create a useful (currently non-existing) tool for an integrated assessment of Danish environmental and climate policies by the ministries and institutions represented in the advisory group as well as by other relevant ministries and organizations and by independent researchers. The code for the GREEN REFORM model will be made available on an open source basis along with a baseline data set for the model. Important findings from the project will be disseminated in the form of scientific journal articles and conferences and via more popular policy briefs aimed at a broader audience. The involvement of two Ph.D. students and a post doctoral researcher in the project will help to alleviate the current shortage of advanced computable general equilibrium modeling skills among Danish economists. Most importantly, the development of the GREEN REFORM model will allow policy makers to undertake a more systematic, comprehensive and consistent evaluation of the environmental impact of public policies and a more rigorous assessment of the relative effectiveness of alternative environmental and climate policies.

Background of senior researchers

Professor Peter Birch Sørensen has considerable experience in developing computable general equilibrium (CGE) models like the REFORM model, as documented by the publications highlighted in his enclosed publication list. He also has extensive experience with analyses of Danish environmental and climate policies as a former chairman of the Danish Environmental Council and current chairman of the Danish Council on Climate Change. Research Director Peter Stephensen likewise has many years of experience with CGE model building. Particularly relevant for the present project, he developed a model of Denmark's transition to a fossil-free energy system for the Danish Climate Commission in 2010.

Peter Birch Sørensen will allocate a major part of his research time to the GREEN REFORM modelling project over the next 3½ years.

Resources and required additional funding

The project has recently received funding from the Carlsberg Foundation amounting to a total of 3,766,191 DKK to be spent over the period from September 1, 2017 until December 31, 2020. The Carlsberg grant will be spent as follows:

- One post doctoral researcher (expected to be appointed by November 1, 2017): 1,520,453 DKK
- One Ph.D. student (expected to be appointed by September 1, 2017): 1,661,738 DKK (including tuition fee and field trip)
- Research time and project management time for Peter Birch Sørensen: 400,000 DKK
- Conference and travel: 184,000 DKK

The project has also received indirect support through a grant from the KR Foundation which is financing a Ph.D. student at the Department of Economics of the University of Copenhagen whose Ph.D. project focuses on the theoretical and empirical basis for estimating a Green Net National Product for the Danish economy. This Ph.D. student is expected to spend about half of her research time on the GREEN REFORM modelling project over the next 2½ years.

The participation from the Department of Economics of one post doc, two Ph.D. students specializing in Environmental Economics and Peter Birch Sørensen should ensure that the modelling efforts can benefit from up-to-date knowledge of the relevant theory, methodology and empirics from the field of Environmental Economics. However, the success of the project also depends on the extensive expertise and experience of the DREAM modelling group when it comes to computable general equilibrium modelling, including programming skills, solution techniques, model testing and access to data bases. In particular, since the goal of the project is to develop a model that is consistent with the

new modelling framework to be developed by DREAM for the Ministry of Finance, participation of the DREAM group in the development of the GREEN REFORM model is indispensable.

We estimate that successful completion of this modelling project will amount to 12 months of work by an experienced DREAM staff member plus 12 months of student research assistance, both spread out over the next 3½ years. We are thus applying for the following amount of supplementary funding for the GREEN REFORM modelling project:

One man-year of salary for a special consultant (specialkonsulent):	541,512 DKK
One year of student research assistance:	80,000 DKK
Overhead (20%):	124,302 DKK
Total:	745,814 DKK

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References

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